

Electric Propulsion Technology

Electric propulsion includes any plasma propulsion device that derives its energy from electrical sources. The momentum change induced and the resulting propulsive accelerations may result from various electrothermal, electrostatic, or electromagnetic mechanisms. Applications include orbit transfer, maneuvering, maintenance, and disposal in low earth orbit, planetary space, and on interstellar platforms. Advanced materials are required that do not experience significant degradation in properties during long duration, up to 20 years, exposure to hostile environments including high temperatures and intense space radiation. These include materials for the following applications: high voltage insulation; electronic components; high strength conventional magnets; high transition temperature, critical field and mechanical strength superconducting magnets; high efficiency solar cells; light weight and high voltage capacitors, easily obtainable, easily ionizable, non-contaminating fuels, and long-life discharge initiation electrodes. In addition, data are needed for sputter yield during low energy sputtering.

Current usage – life of high voltage (200V) insulation is less than 10 years. The projected lifetime requirements are 20 years for voltages up to 1000V. Potential polymeric and ceramic materials have not been demonstrated and tested for the effects of high levels of galactic radiation exposures at various temperatures for long time periods. The key issues are whether candidate materials can maintain required dielectric strengths and other desired properties for the required duration.

Silicon based electronic components are highly sensitive to radiation damage and their performance rapidly degrades at temperatures above about 200C.

The development of new materials for electronic components with enhanced radiation tolerance, higher operating temperature limits (300 C and above) and longer operational lifetimes than provided by current silicon-based device architectures is a significant scientific challenge that requires extensive fundamental research.

There is a lack of lightweight permanent magnets with the specific energies (up to 1MJ/kg) that can survive temperatures up to 400C for 20 years exposed to galactic radiation and plasma streams. Current capabilities are about 30 kJ/kg, maximum coercive fields of about 3.5×10^4 oersteds and maximum operating temperatures about 210C. Basic research is required to identify new materials with significantly higher permeabilities and coercive fields.

Large advancement in the field of superconducting magnet materials technology will be required to approach the desired 1MJ/kg energy densities. Because of the rapid decrease of the critical fields with increasing temperature, high field superconducting magnets operate at liquid helium temperatures. The containment of the cryogenic fluids used for cooling results in large weight penalties. The achievement of the 1MJ/kg goal will require not only a large increase in the critical fields but also in the strength of the

materials used for the magnet components because of the large forces that are generated by the fields.

Single transfer electric propulsion through the radiation belts of some of the planets (e.g., Jupiter) causes approximately 30% degradation of performance of solar cells in 60 days. Solar cells that provide efficiency degradation of less than 5% over 600 days when passing through the radiation belts are required. A better fundamental understanding of the radiation damage mechanisms involved and the development of new materials and device structures that are less sensitive to radiation damage needs extensive research.

Pulsed Plasma Thrusters need at least 50% mass reduction of existing capacitors and the elimination of the oil that tend to leak and contaminate the spacecraft. Basic research is needed to identify efficient solid-state material replacements for high voltage oil-filled capacitors that maintain their integrity in the hostile environments.

There is a strong need for fundamental research in several additional areas, such as alternative Pulsed Plasma Thruster fuels to replace teflon; materials that reduce spark plug erosion and allow plug firings of 108 or more; and cathode materials for ion propulsion having lifetimes of 10 years in a 1000° F temperature environment.

Magnetoplasmadynamic thrusters operate by discharging a high current arc between a central cathodes and concentric anodes. The arc currently ionizes the propellant gases to form a conducting plasma. The cathode temperatures approach 2000K. Basic research is needed to identify new low work function, high emmissivity cathode materials with mechanical properties equal to or superior to currently used LaBa 6 that can operated in a 2000K temperature environment for long time durations.

